

Infrared Imaging 1941-2001

Ted Raab

Mid-infrared Rhizosphere Atlas
(MIRA)

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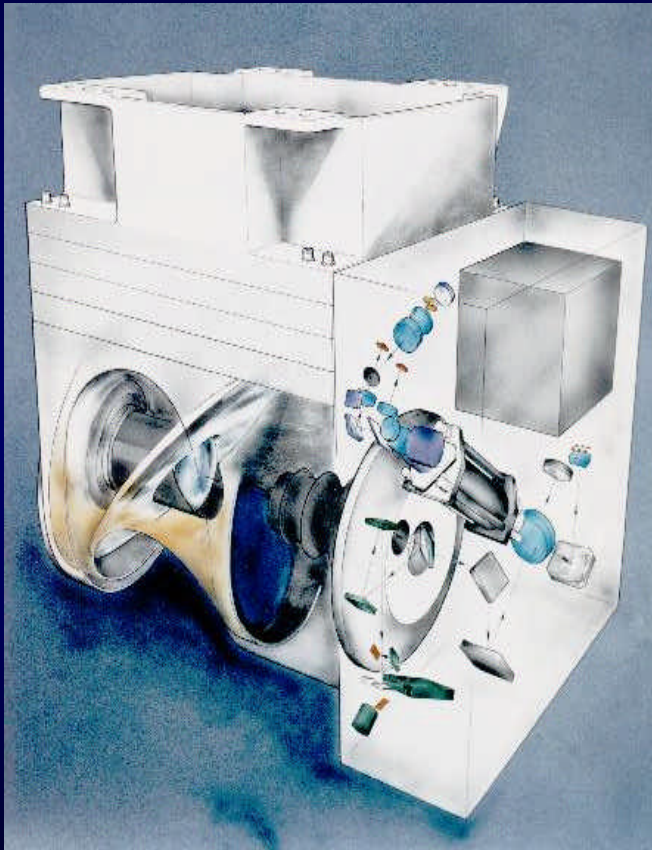
What Is the Infrared ?

- **Near IR** (<1 - 3 μm); Remote sensing or planetary science applications
- **Mid IR** (3 - 20 μm); Chemistry/biology
- **Far IR** (20 - 200+ μm); Physics/biology?

Methods for IR Detection

- Photographic film (“color IR”)
- PMT’s
- Solid-state devices
- Focal-plane arrays

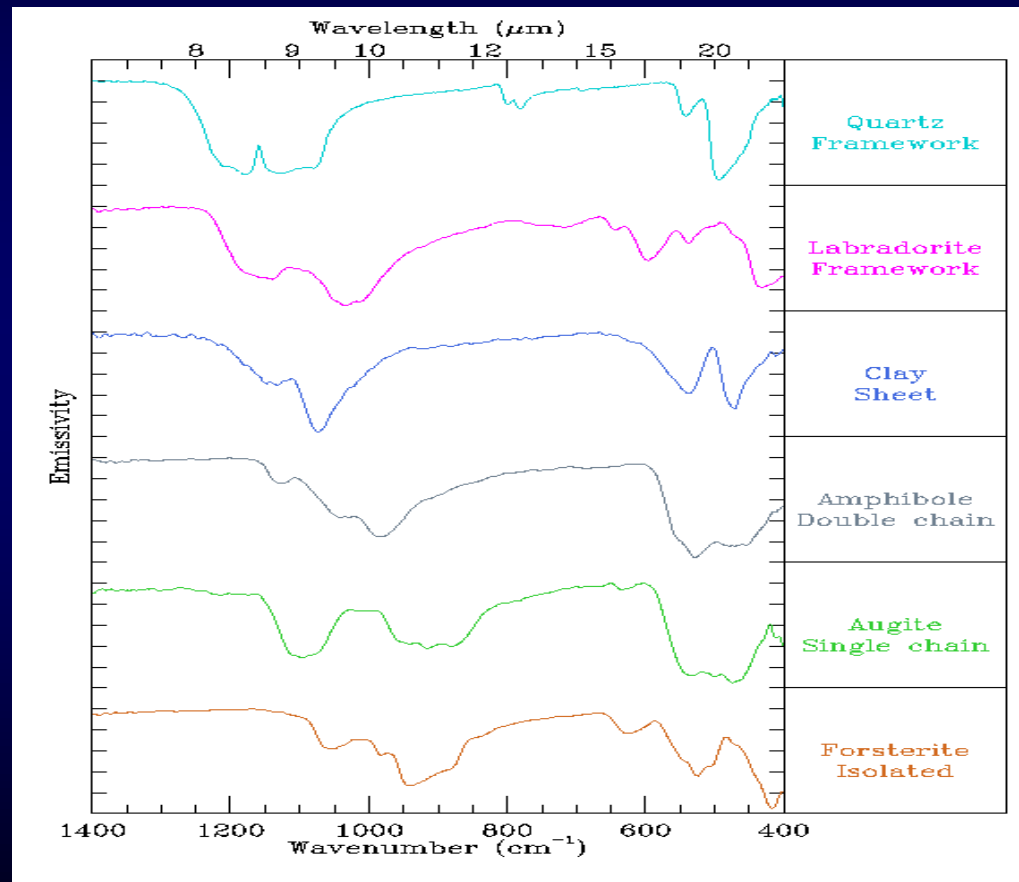
Thermal Emission Spectrometer



Most successful of the interplanetary imagers, currently in orbit around Mars (Mars Global Surveyor).

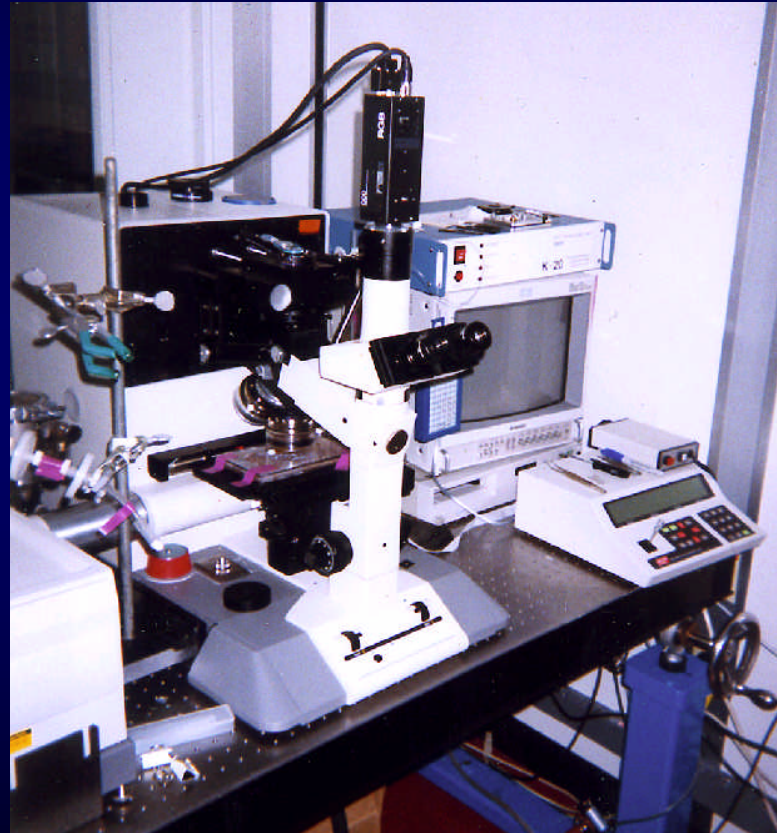
Has returned about 10^9 hi rez images of ices and surface minerals

Planetary materials in the mid IR

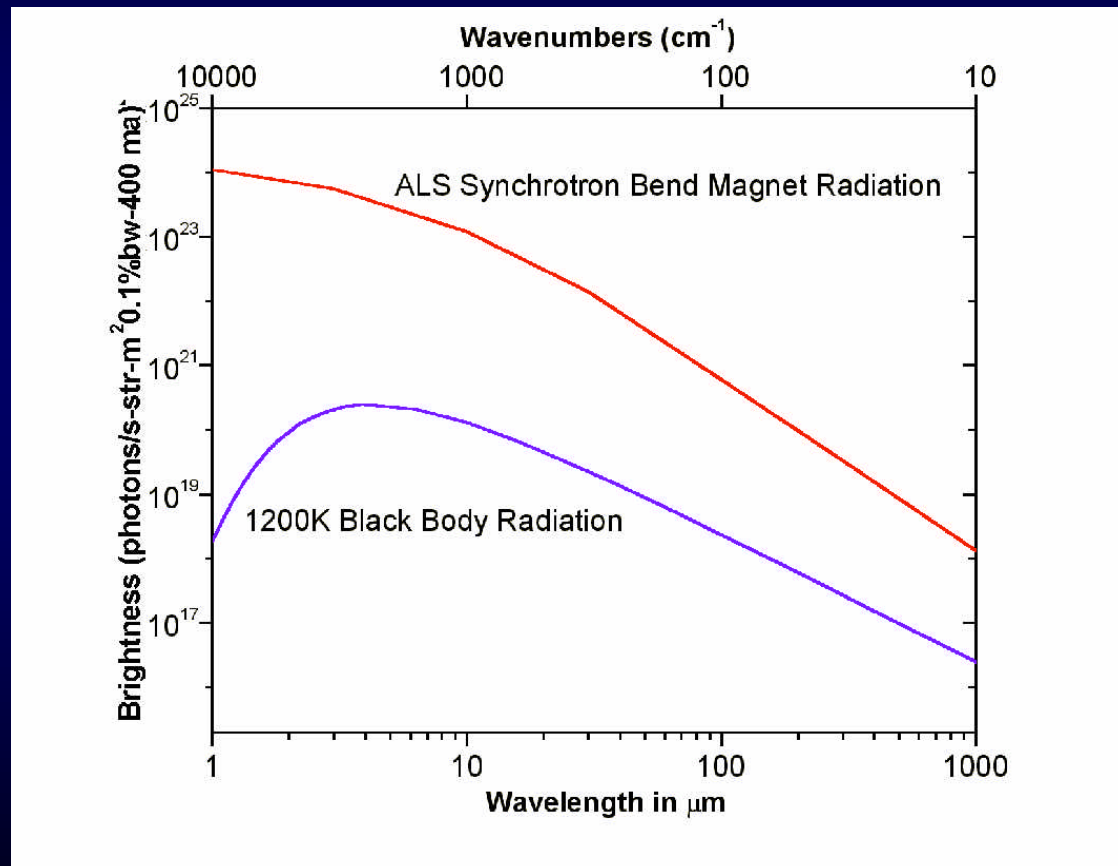


The Infrared Microscope

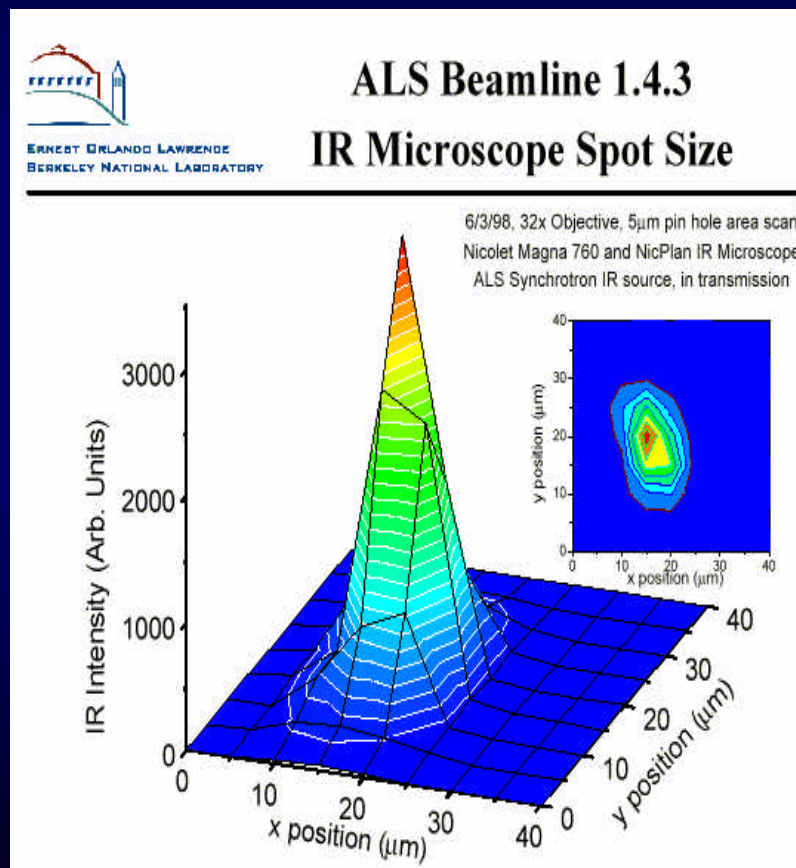
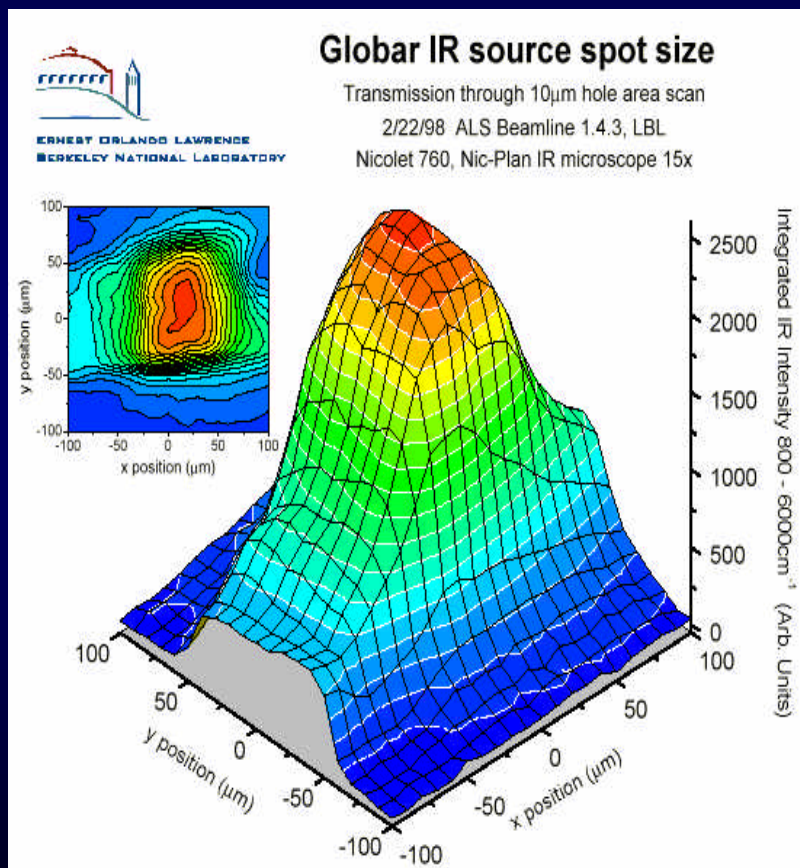
- Invented ~ 1986
- Optics limited the spatial resolution
- Low radiation thru small apertures gave poor spectra



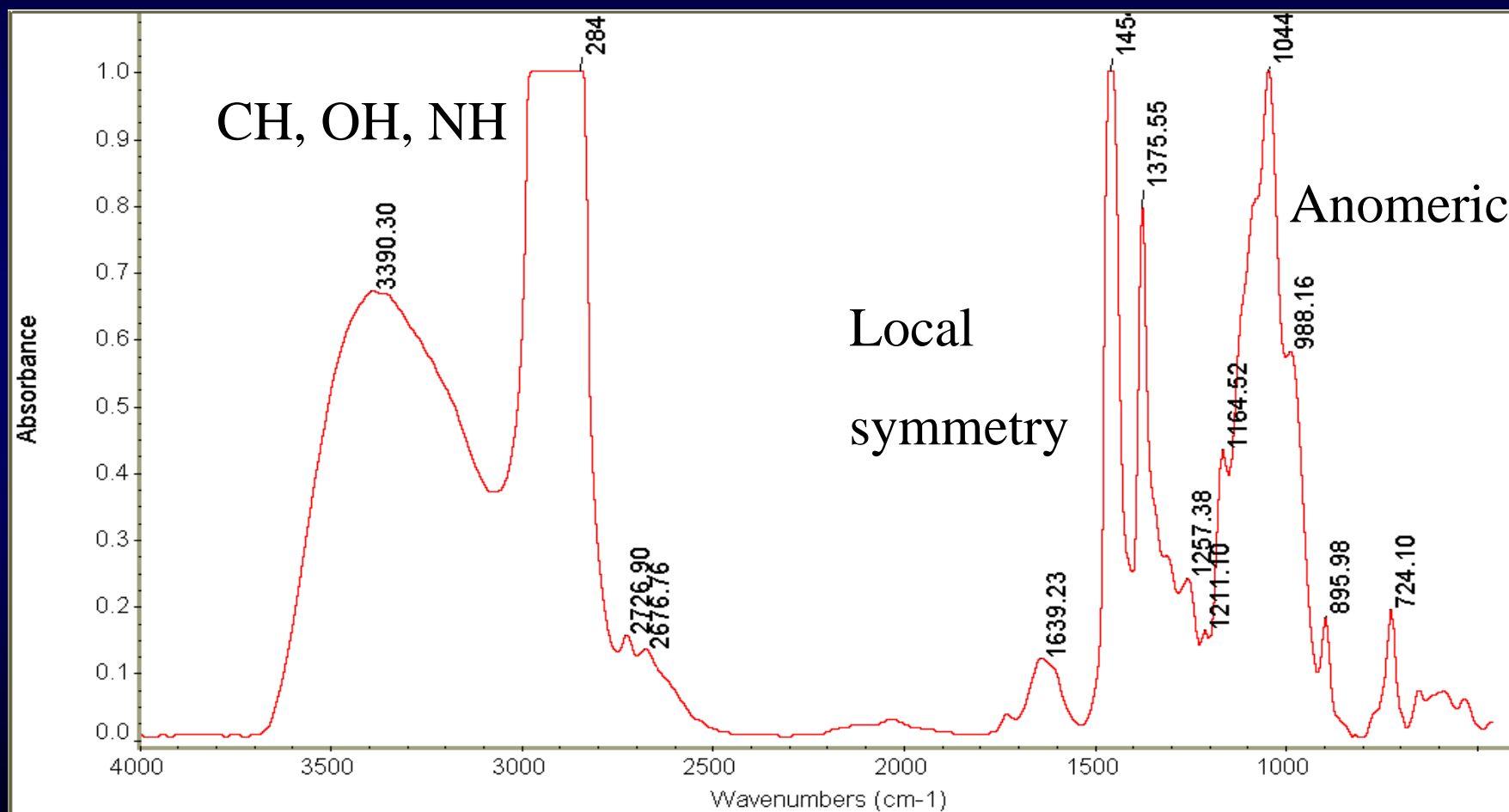
Synchrotrons As a Source of IR



Comparison of IR spot sizes



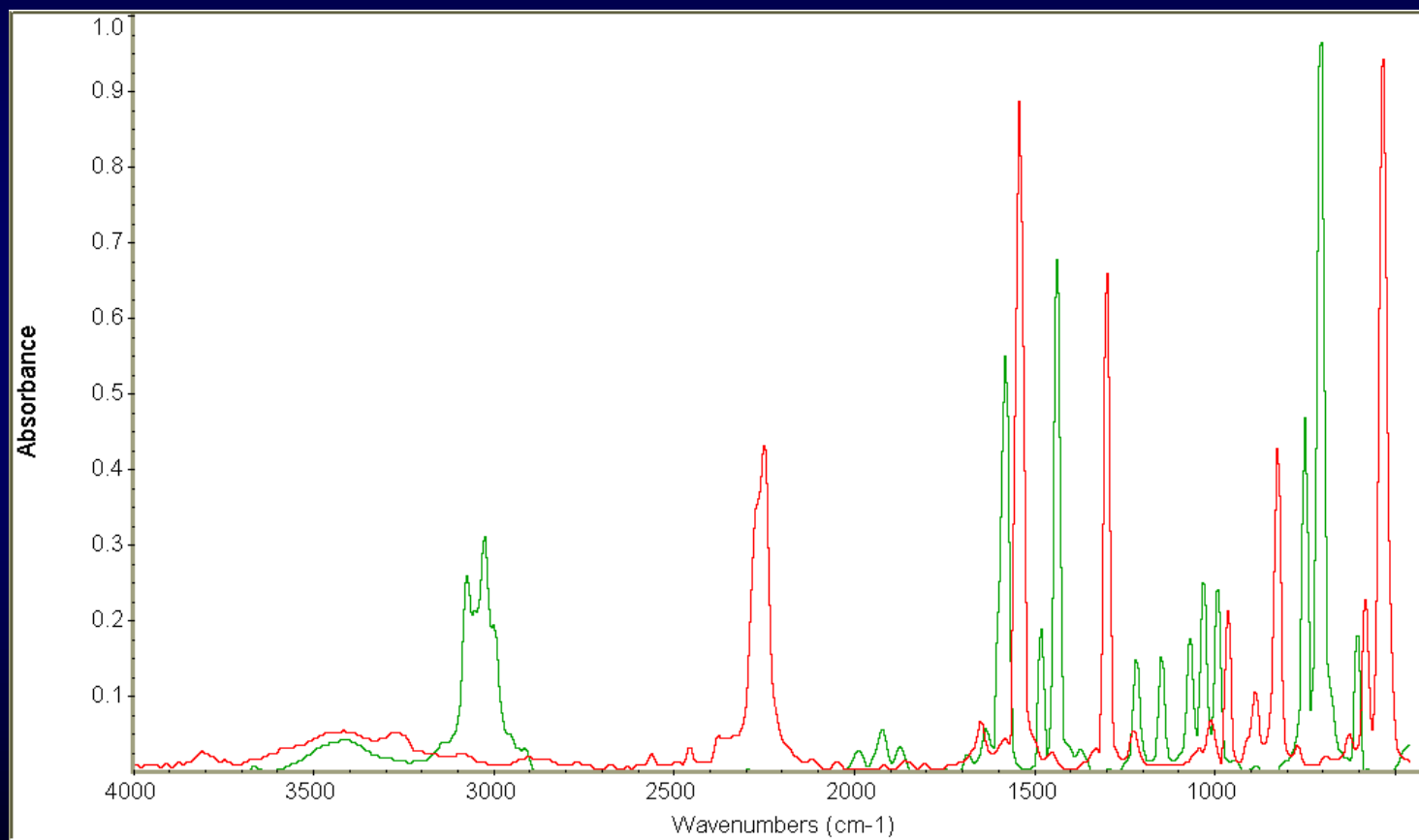
Polysaccharide spectra



Mechanisms of IR contrast

- Mass changes
- Geometry
- Vibrational coupling
- Bond order
- Electronic effects

Isotope Effects on IR Spectra



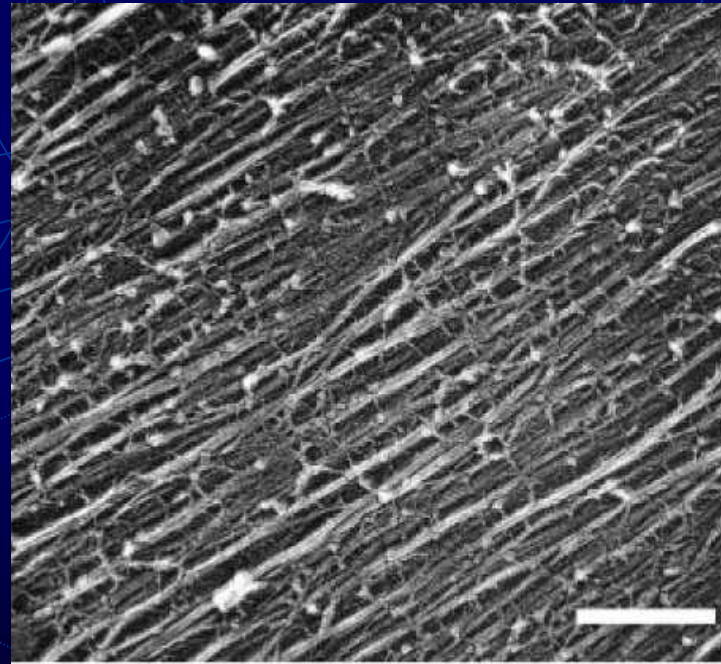
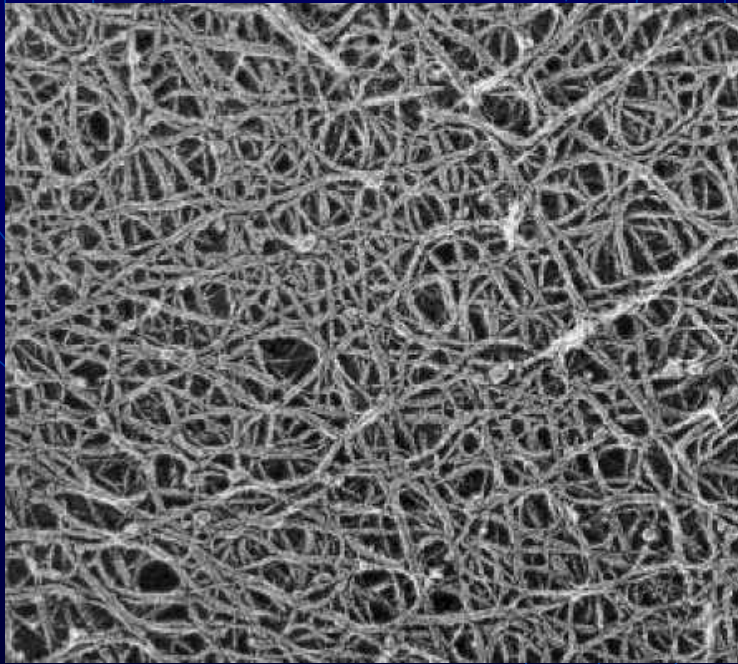
D5-pyridine vs. H5

Orientation of Cells and Associated Polymers



- Several hundred μm of root cells from an intact legume root
- Oriented along the growth axis (upper left to lower right)

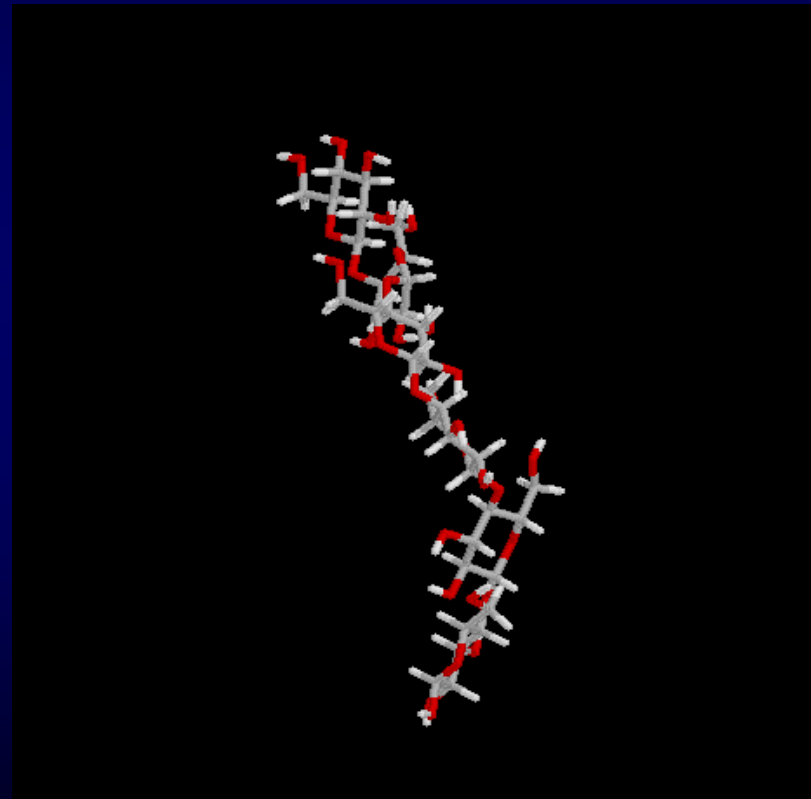
Oriented deposition of Polysaccharides



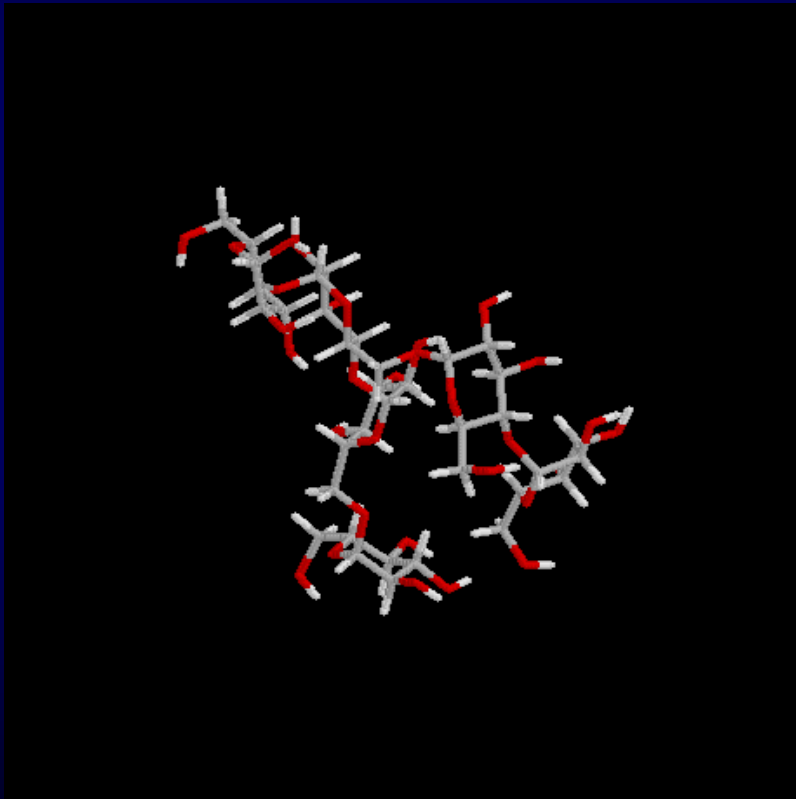
From: McCann, Wells & Roberts J Cell Sci 96,323

Linear Structural Polymers

- Cellulose is a β -(1,4) glucose polymer
- Laid down in long parallel strands
- Some IR features show strong polarization



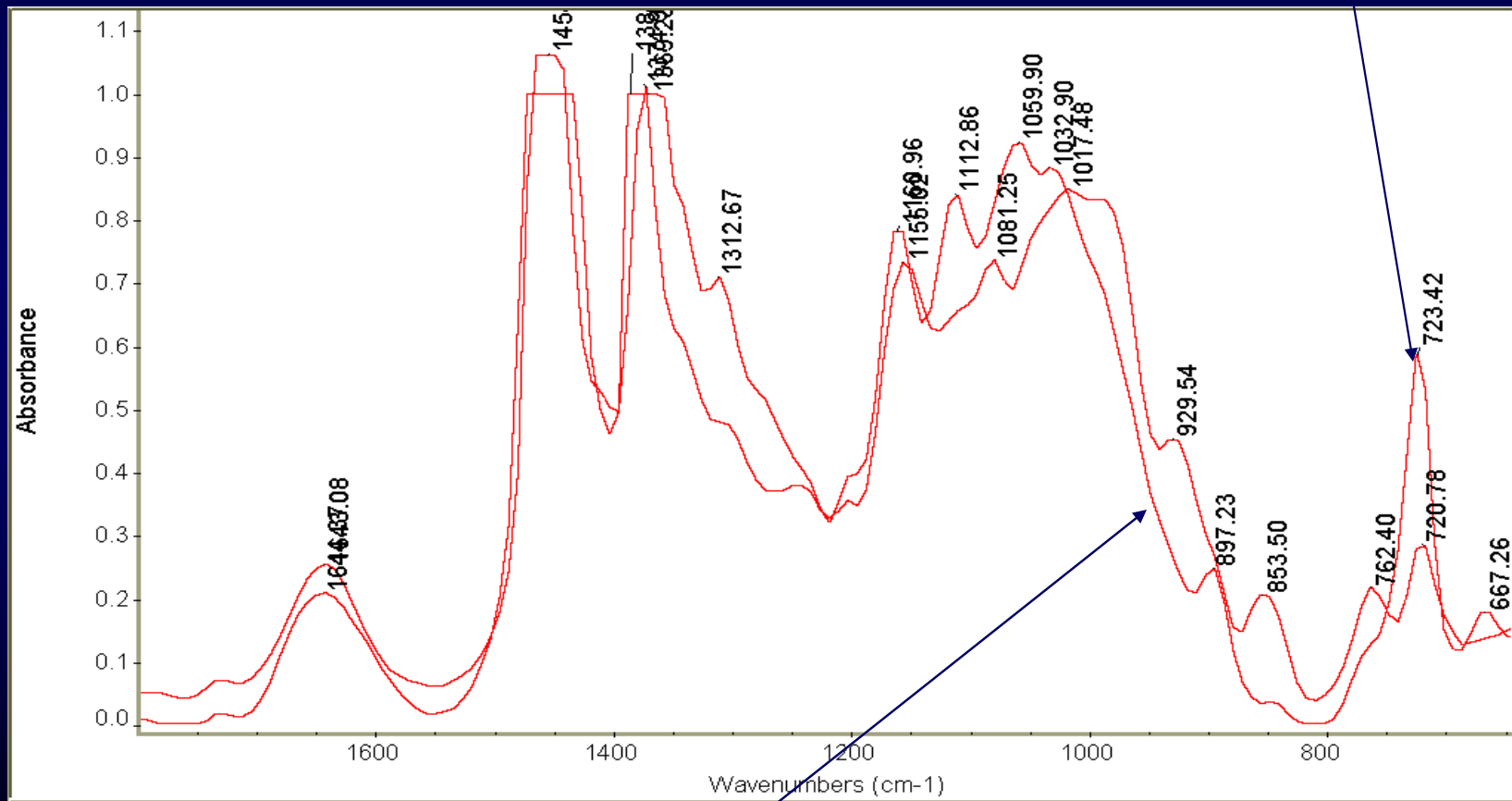
Amorphous/branched Polymers



- Starch is an α -(1,4) glucose polymer, often branched
- One of the principal energy storage forms for plant growth

Compare Biological anomers

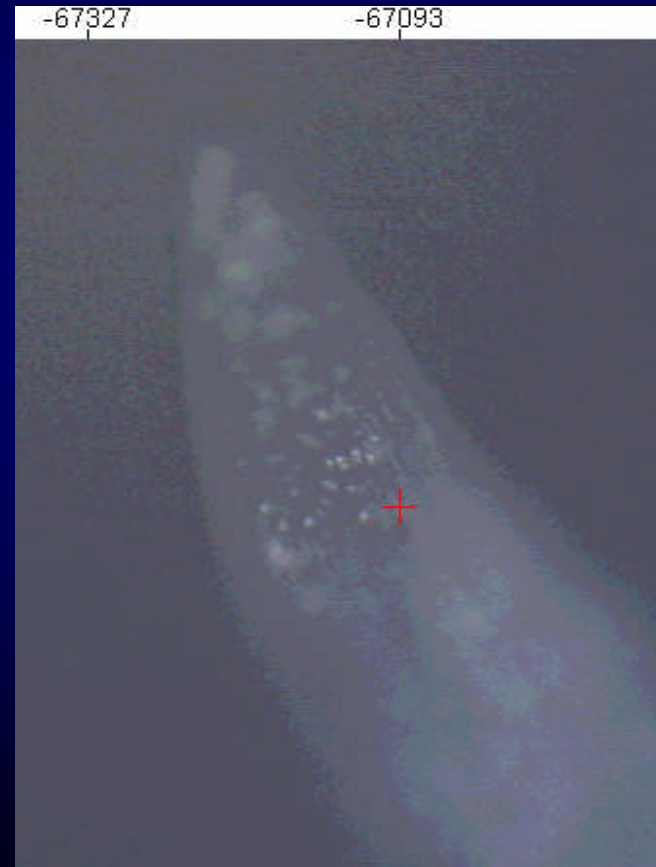
cellulose



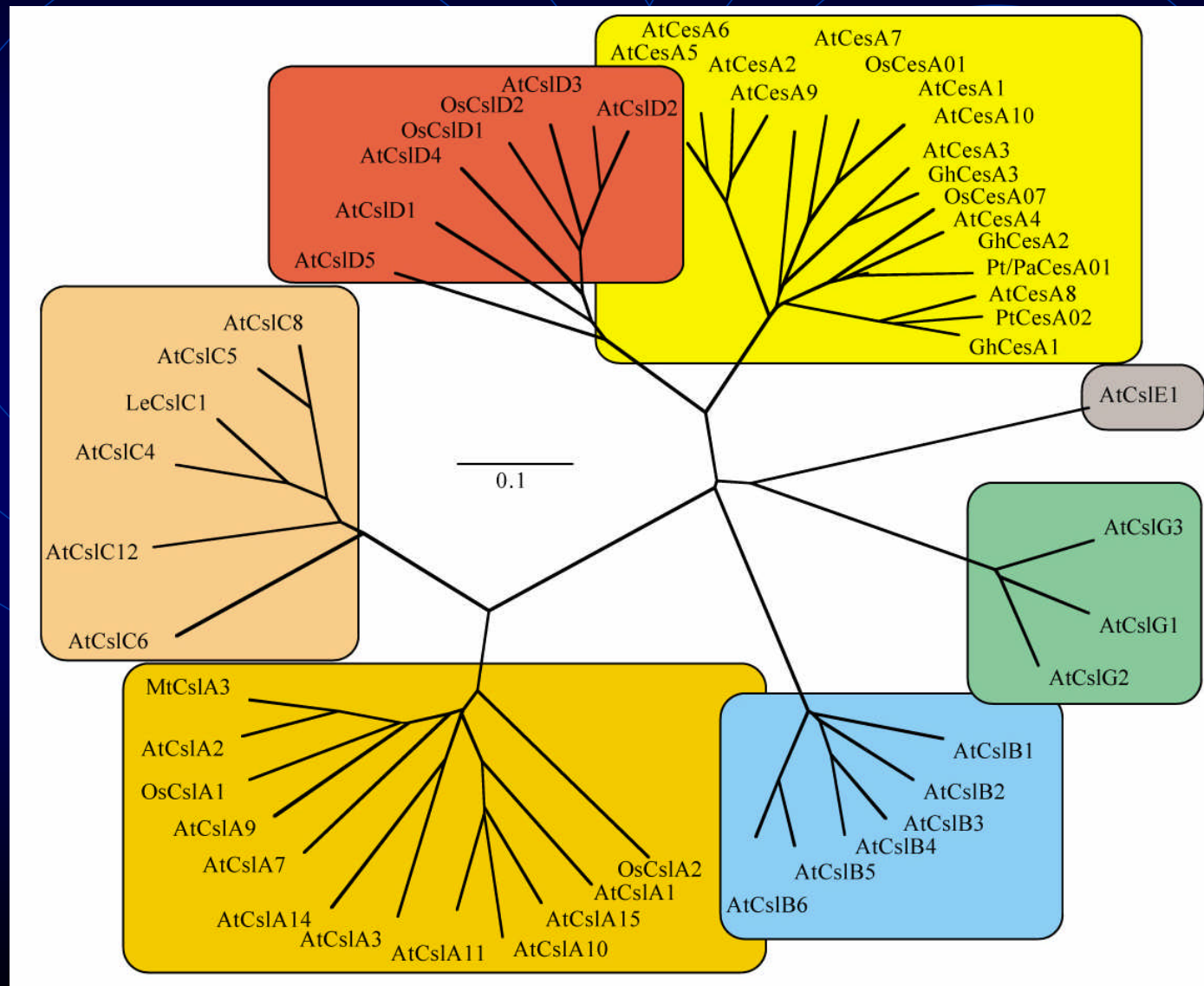
starch

Connecting Polymers With Biology

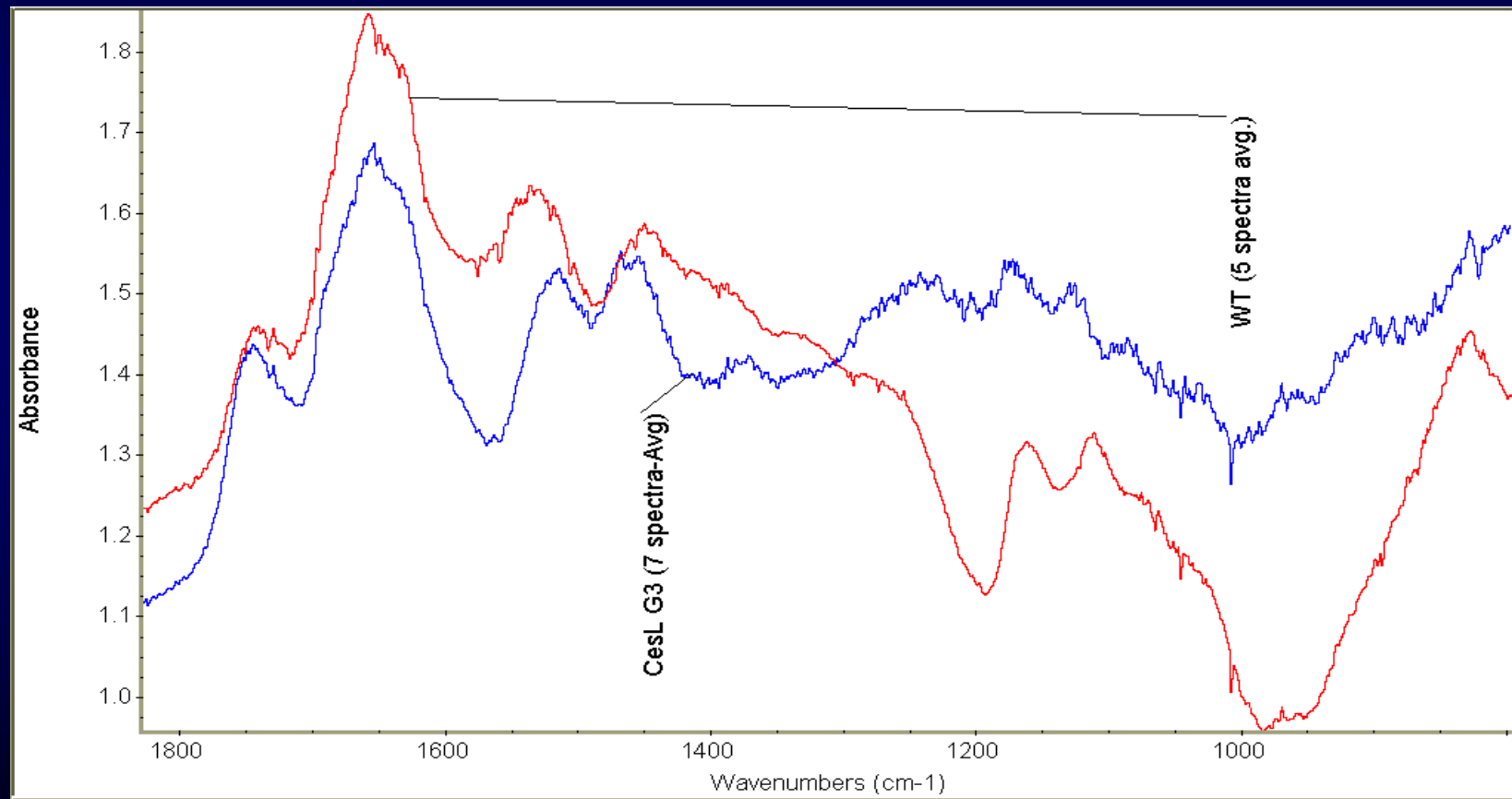
- Need to characterize the chemical composition of the cell walls in different tissue types
- Mutants lacking one of the Csl-x genes are compared by IR



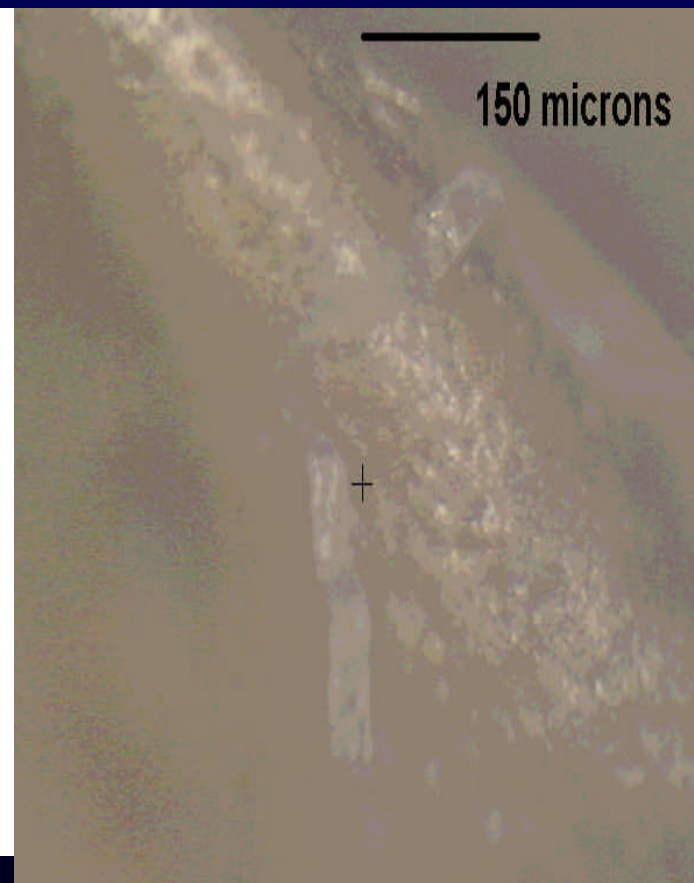
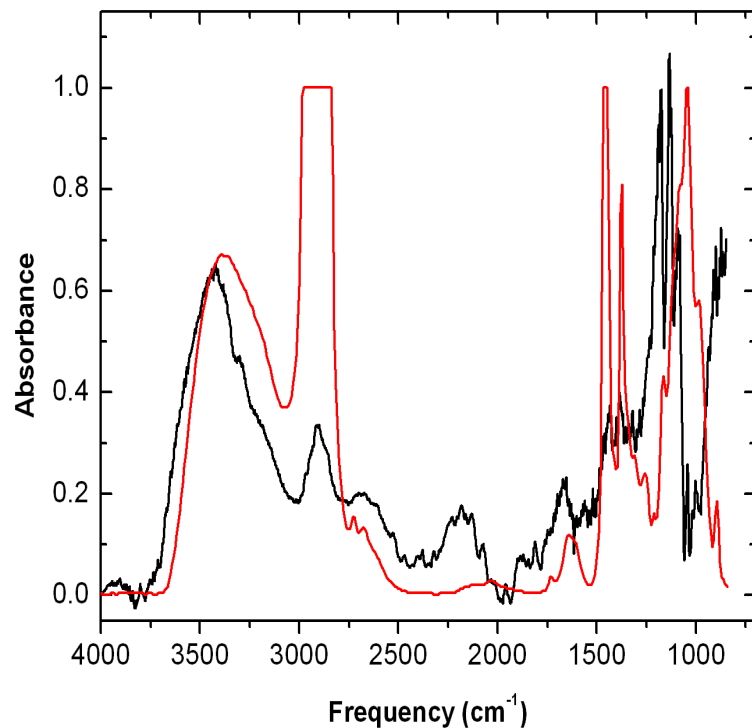
The cellulose synthase gene family



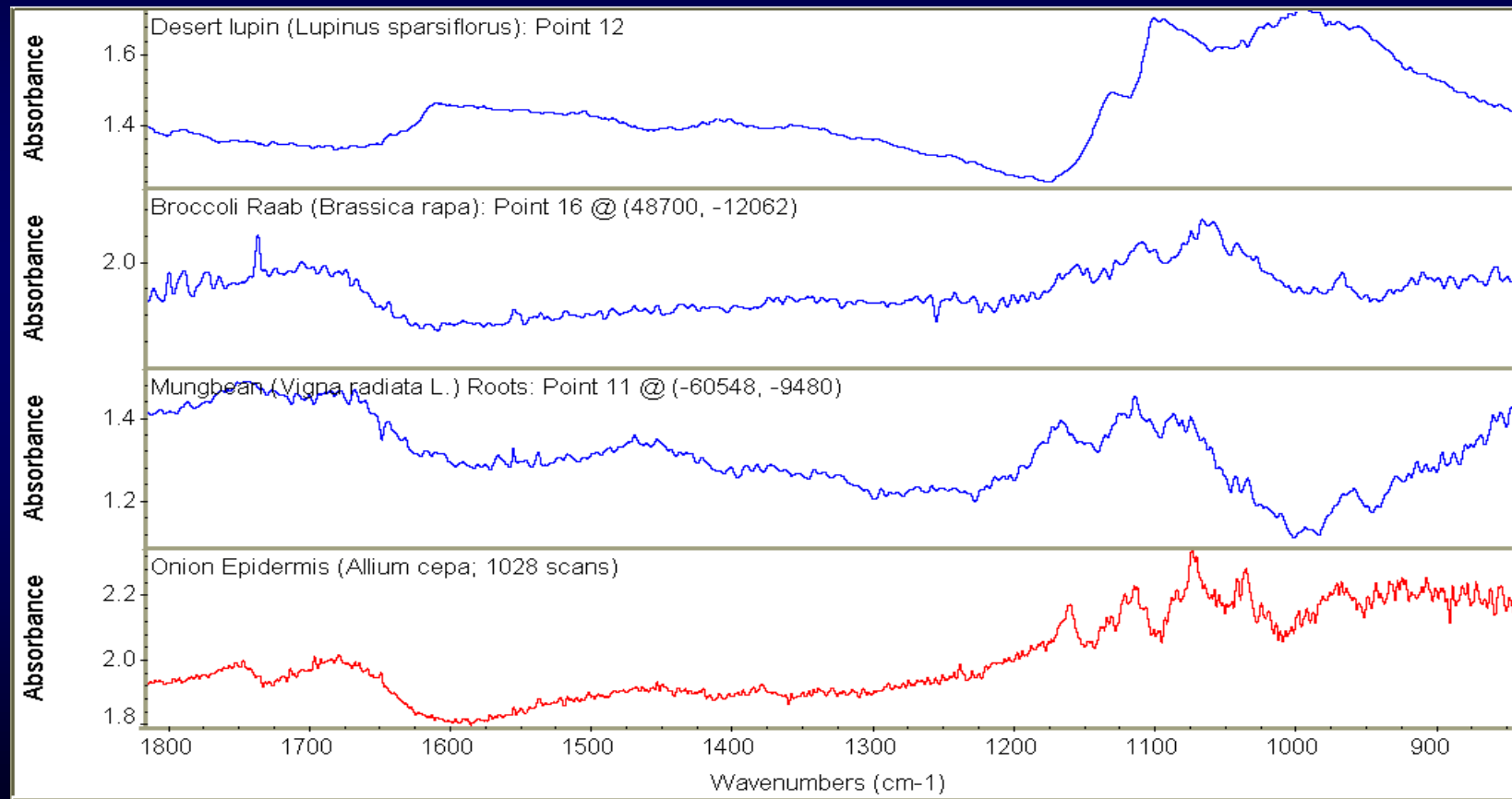
Comparison of Arabidopsis leaves



Glucomannans As Seed Builders



Comparing root fingerprints



Experimental design

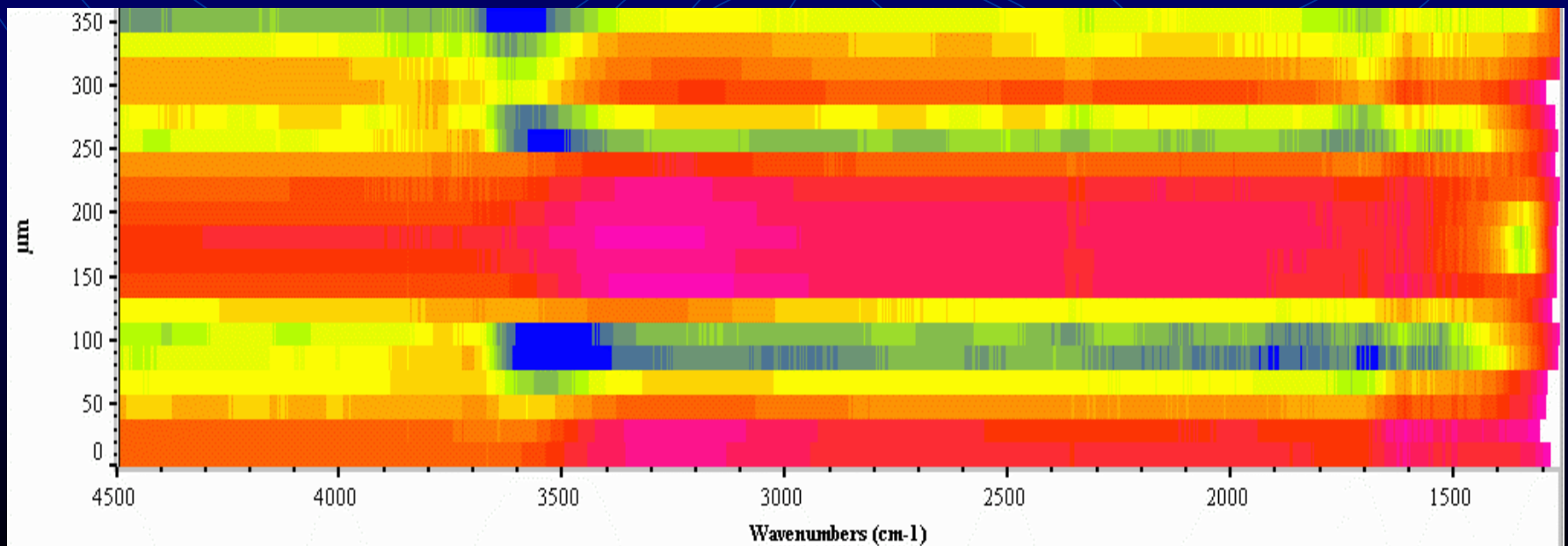
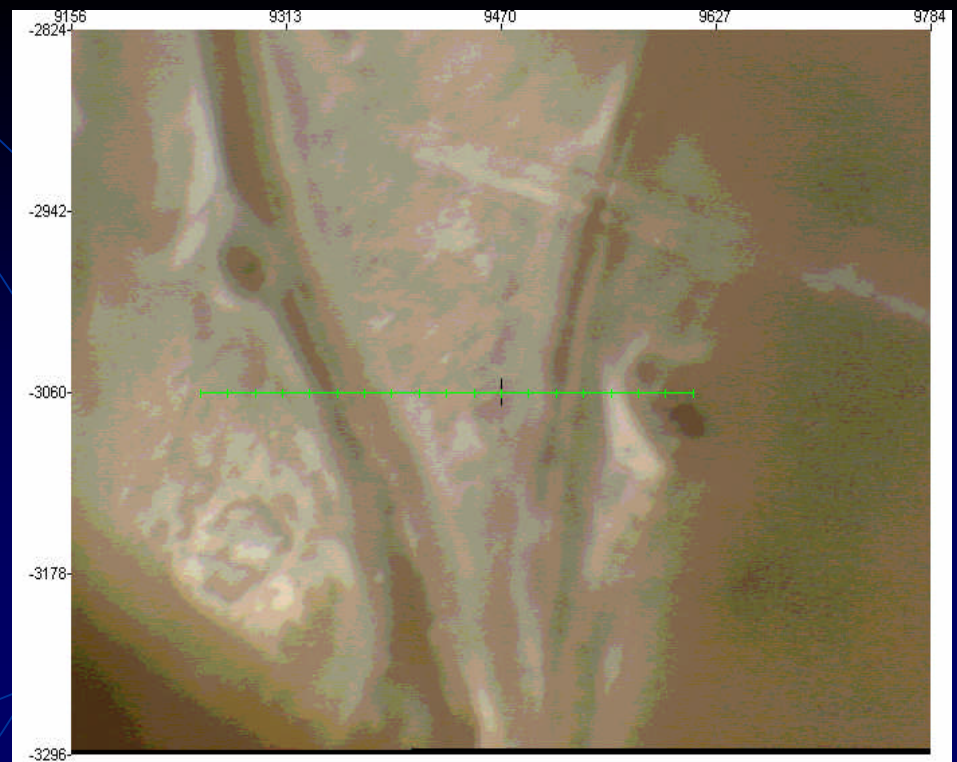
- Thin-rhizobox geometry for growing plants in sand/silt culture ($2\pi d / \lambda > 10$)
- Spectra from IR microscope acquired through IR-transmissive ZnSe windows.
- Perturb the plant-soil system simply ...

IR rhizobox

Polycarbonate box
with soil and a ZnSe
IR transparent
window over root
zone.



Spectral map of fine roots on a grain of sand



Conclusions

- Rhizosphere chemistry in our legume system has significantly different chemistry over 50-75 microns
- Low-phosphorus increases the exudation of protein(s) into the soil solution compared with nutrient-sufficient plants
- SR IR is sensitive to altered root polysaccharide chemistry
- SR IR spectromicroscopy complements soft X-ray and ^1H -MRI, providing better chemical information with spatial localization.

Acknowledgements

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